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FREEZING OF GREENHOUSE-GROWN TOMATOES IN TRANSIT

By

R. C. WRIGHT
Physiologist

and

T. M. WHITEMAN
Junior Horticulturist
Division of Fruit and Vegetable Crops and Diseases
Bureau of Plant Industry

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By R. C. Wright, *physiologist*, and T. M. Whiteman, *junior horticulturist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

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INTRODUCTION

Greenhouse-grown tomatoes are picked and put on the market in the largest quantities during the early winter months. They are usually picked when in a firm, ripe condition, and most of them are marketed in the larger cities to the fancy trade. The total production of these tomatoes is relatively small, and they are usually transported to distant markets by express in less-than-carload lots or by truck to nearby markets.

Greenhouse tomatoes are often quite fragile in appearance, because the outer tissue is more or less transparent and exposes, to some extent, the vascular system which often appears as a delicate veining just under the epidermis. On account of the delicate and transparent appearance of these tomatoes when received on the market, dealers frequently protest that the tomatoes have been chilled or exposed to too low temperature while in transit.

Accordingly, tests were made on greenhouse-grown tomatoes to determine the effect on their appearance of actual freezing and also of exposure to a temperature not quite low enough to cause actual freezing.

FREEZING WHILE UNDISTURBED

On December 8, 1930, a shipment of tomatoes was received direct from the Ashtabula Growers Association, of Ashtabula, Ohio. These tomatoes had been packed and shipped on December 6. The weather was mild at the time, and no evidence of injury by cold was apparent on arrival. The tomatoes were wrapped in tissue paper and packed in two layers in attractive splint baskets that were lined with a single layer of tissue paper. Outside the basket there was a single layer of brown wrapping paper, and over the

top of the basket and under the handle was tied a lid of corrugated fiber board with the shipper's label on top. The weight of the baskets and contents was about 9.5 pounds each. The method of packing is illustrated in figure 1.

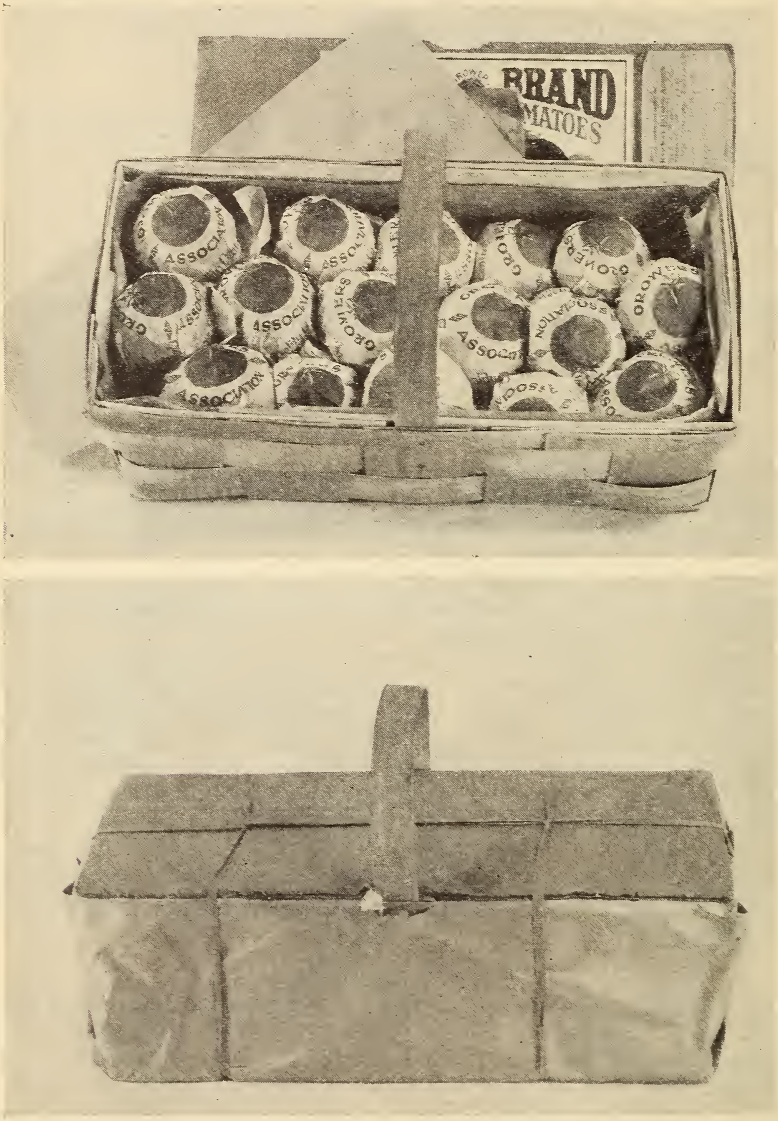


FIGURE 1.—Shipping packages for greenhouse-grown tomatoes.

One basket was unpacked, and electrothermocouples were placed in the centers of tomatoes located at the bottom end, the bottom center, the top end, and the top center of the basket. In addition a thermocouple was placed so as to record the air temperature between the tomatoes at the center near the top layer. The basket was then

repacked as before and was subjected to a temperature of about 17° F. The temperatures indicated by the thermocouples at the various locations were recorded at half-hour intervals for 24 hours. At the end of this period most of the fruits had frozen, but none was frozen solid. The rate of cooling and the freezing temperatures of

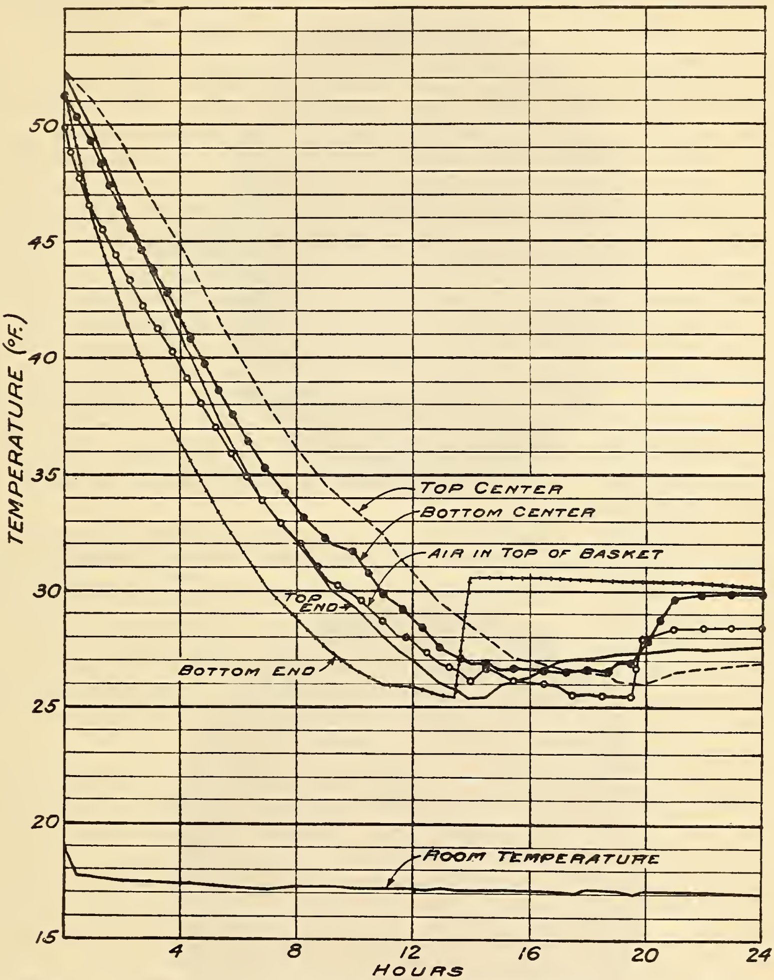


FIGURE 2.—Temperature in a shipping basket of greenhouse-grown tomatoes held 24 hours at a room temperature of about 17° F.

tomatoes at the given positions in the basket are shown in figure 2.

The remaining tomatoes were unpacked and divided into two approximately equal lots, one of which was stored at 30° F., and the other at 50°. After 24 hours the tomatoes held at 17° and 30° were transferred to storage at 50°, at which temperature the check lot had been continuously held. After another 24 hours the tomatoes in all lots were carefully examined for freezing injury. Although the freezing points of these tomatoes were found to vary from 30° to 30.5° and the exposure was long enough to allow the tomatoes to

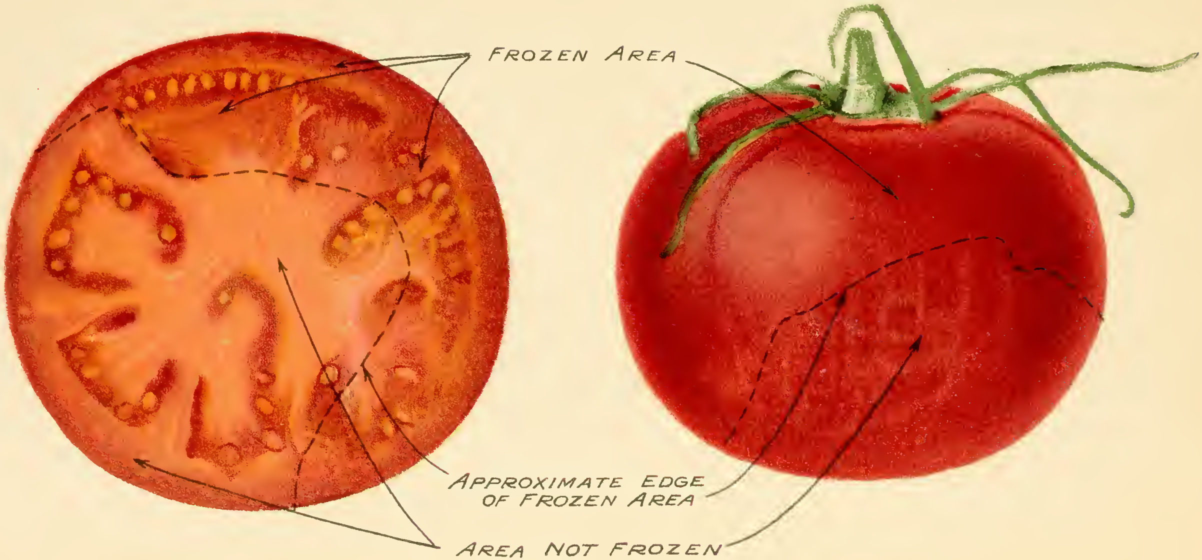
come to this air temperature, there was no difference in the appearance of those exposed at 30° and the check lot held at 50°. However, in the lot held at 17°, evidence of freezing was noted in nearly all specimens except a few near the top center of the basket.

Figure 2 shows that the first tomato to freeze was at the bottom end of the basket. Here freezing began after 13½ hours, when the specimen had undercooled or cooled below the freezing point to 25.5° F. The freezing point, which was identified by the temperature rising and remaining constant for some hours, was 30.5°. This specimen started to undercool after about 6½ hours. The next tomato to freeze was at the top end of the basket. Here freezing began in 14 hours, after the fruit had undercooled to 25.4°, the undercooling starting after about 9 hours, but the actual freezing point apparently was not reached before the end of the test because the temperature was still rising at that time. The tomato at the bottom center began to freeze after 18 hours when it had undercooled to 26.9°. Undercooling started after about 10½ hours. The temperature then rose to 29.8°, which may represent the freezing point of this specimen. However, owing to the failure of the other fruits to come to their freezing points quickly, and also to the rise in the temperature of the air near the top of the basket, due probably to the liberation of heat from the surrounding freezing fruits, the ultimate freezing point of this and the other fruits was probably not reached during the test. The tomato in the top center of the basket began to freeze in about 20 hours, after undercooling to 26°.

The sudden rise in the air temperature near the top of the basket is interesting, as it illustrates the point that during freezing heat known as heat of crystallization is given off. In this instance the heat very probably delayed the freezing of some fruits near others that had begun to freeze. Assuming the average freezing point of these tomatoes to be between 30° and 30.5° F., from 6½ to 9 hours were required for the fruits in the more exposed bottom ends of the basket to cool from 50° to the freezing point when danger of actual freezing began.

The results obtained here, and also those from many experiments with other plant products, show that the temperature of living plant tissue can be lowered below the freezing point without actual freezing. This phenomenon is known as undercooling, a state in which plants or plant parts are likely to freeze at any time. Usually a disturbance by a sudden jar as in handling will start freezing, although, as in this test, freezing will eventually follow even if the product remains perfectly quiet. As will be shown later, undercooling may persist for some time in spite of a certain amount of jolting or agitation such as occurs during transportation. Freezing injury to plant tissues takes place only with actual freezing or the formation of ice crystals.

It should be borne in mind that these results represent what might take place in any basket of tomatoes placed by itself and surrounded by air at a similar temperature. When a number of baskets of fruit are stacked or piled together, as under ordinary transit conditions, the rate of cooling would be expected to be much slower. It is thought that if greater protection from possible freezing is desired, a corrugated fiber lining can be placed in each basket before packing, thus affording some insulation at a relatively small cost.



L. C. C. Krieger, Pinx.

Freezing injury in a greenhouse-grown tomato

Lith. A. Hoen & Co., Inc.

Freezing injury in many of the tomatoes was detected by an external examination. Where a limited amount of freezing took place, the irregularly shaped injured areas were marked by a somewhat darker color, accompanied by a water-soaked appearance. The veining mentioned (p. 1) as showing under the epidermis and forming the basis of claims for freezing damage was not visible in the frozen areas. Where the entire specimen was injured it appeared quite soft and water-soaked.

When frozen specimens were cut open, the injured areas of the outer wall or outer fleshy rim, and the septae, or partitions between the pulp receptacles, had a water-soaked appearance which was darker than normal. The vascular strands, which appear on the cut surface of a tomato as small light-yellow dots, were found to be obliterated in the frozen areas. Freezing injury in cut specimens should not be confused with the somewhat darker area found in normal uninjured tomatoes, extending from one sixteenth to one eighth of an inch into the outer wall just beneath the skin in a more or less regular ring around the entire specimen. When freezing injury occurs the regular outline of this ring is broken in the injured areas which have an irregular dark water-soaked appearance. Plate 1 shows an exterior and an interior view of a partly frozen tomato.

FREEZING WHILE BEING JOLTED AS IN TRANSIT

On April 30, 1931, two additional baskets of greenhouse-grown tomatoes were obtained from the same source as those used in the first test. In each basket thermocouples were placed in tomatoes in the bottom layers located in the two corners at one end, on one side half-way between the ends, and in the center; and in the top layers at points directly above those in the bottom layers. Thermocouples were also placed so as to record the package air temperature between the fruits in the center of the top layers. The baskets were then wrapped as they were when received.

In a storage room maintained at about 20° F., one basket was left undisturbed, and the other was placed in an apparatus constructed to produce jolting similar to that encountered by produce in transit. This apparatus consisted of a small truck attached by an eccentric arm to a reduction gear, which was in turn operated by a small motor. The truck traveled back and forth over a track, across which were fastened two quarter-inch cleats. The tomatoes thus received repeated jolts at the rate of 38 per minute throughout the test. Temperature readings were taken each hour for a period of 33 hours, followed by a period with no readings until the end of 48 hours, when the test was terminated and the tomatoes were examined to determine the amount of freezing injury.

Figure 3 shows the temperature of the various fruits in the different positions as well as the air in the packages. As in the former test, freezing first started in the bottom corners of the baskets and occurred last at the top centers. The fruits in the undisturbed basket undercooled more and for longer periods than did those in the jolted basket, although, as will be noted, a certain amount of undercooling occurred in the jolted basket.

The fruits in which temperatures were recorded in the different positions showed that of those in the bottom corners of the jolted

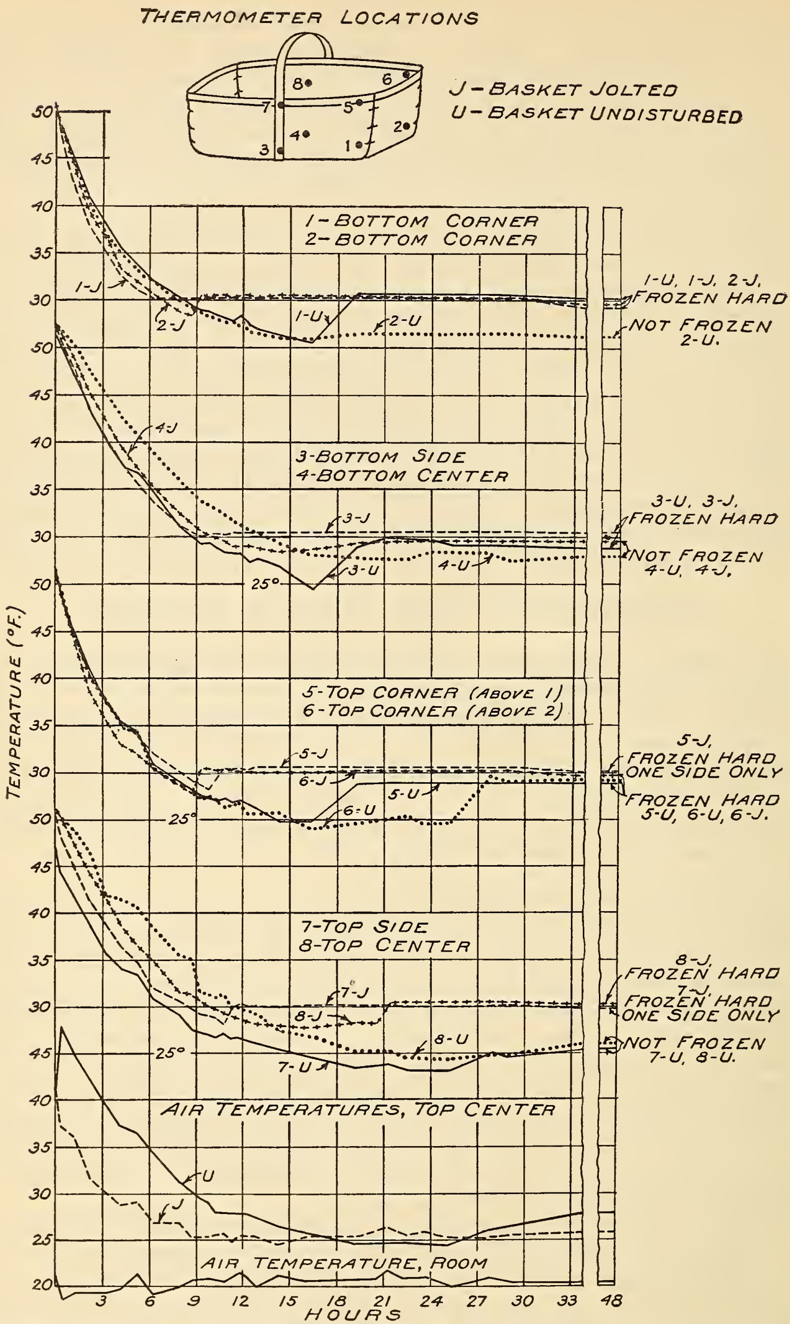


FIGURE 3.—Temperatures in a shipping basket of greenhouse-grown tomatoes while being jolted and in one undisturbed; both in a room temperature of about 20° F.

basket, one apparently started to freeze without perceptible undercooling after about 6 hours, and the other undercooled to 28.3° F. after about 8½ hours and remained undercooled about 2 hours, when freezing began, as denoted by a rise in the internal temperature at that time. Both of these fruits were frozen hard at the end of the test. In the undisturbed basket, one tomato in the bottom corner undercooled to 25.5° F. after about 16 hours, having started to undercool after about 8 hours. The other specimen started to undercool after about 8 hours and remained undercooled to the end of the test, when no evidence of freezing injury was apparent. The lowest undercooling point reached by this tomato was 26°.

Of the remaining fruits in the bottom layer, the one in the side of the jolted basket showed evidence of a slight undercooling after about 10 hours and an hour later started to freeze. This fruit was frozen hard at the end of the test. The other fruit in the center started to undercool after about 10 hours, and remained undercooled throughout the test. The lowest temperature this fruit reached was 28.4°. In the bottom layer of the undisturbed basket the fruit at the side started to undercool after about 9 hours, reaching its lowest temperature (24.4°) after about 16½ hours, when it started to freeze. It was found to be frozen hard at the end of the test. The fruit in the center started to undercool after about 13 hours and remained undercooled.

In the top layer in the jolted basket the corner fruits showed some undercooling after about 7 hours, and one started to freeze after about 9 hours and the other after about 10 hours. At the end of the test one was frozen hard on one side only; the other was frozen hard throughout. In the undisturbed basket both corner fruits in this layer started to undercool after about 7 hours, one reaching a temperature of 24.7° F. and the other 23.9°. The first started to freeze after about 16½ hours, and the other after about 25½ hours. Both were frozen hard at the end of the test

In the jolted basket the fruit at the top side started to undercool after about 8½ hours, but only reached 28.2°. It started to freeze after about 11 hours and was frozen hard at the end of the test. The fruit in the top center of this basket started to undercool after about 11 hours and began to freeze after about 20 hours. The lowest temperature reached was 27.7°. This tomato also was frozen hard at the end of the test. In the undisturbed basket both fruits in the top layer undercooled but did not freeze. The one located at the side started to undercool after about 7½ hours, reaching a minimum temperature of 23.2°, while the one in the center started to undercool after about 11 hours and reached a minimum of 24.5°.

The air between the fruits in the jolted basket cooled more rapidly than in the undisturbed basket. A temperature of 25° F. was reached in about 8½ hours, after which this temperature was maintained approximately throughout the test with minor fluctuations which appeared to follow variations in the storage-room temperature.

In the undisturbed basket the package temperature slowly went down to slightly below 25° F., passing this temperature in about 19 hours. After about 25 hours the temperature began to rise until the end of the test, when 28.2° was recorded. This rise was doubtless caused by the heat of crystallization from nearby fruits that were freezing.

The apparent discrepancy due to the package-air temperatures as recorded being slightly higher than certain fruit temperatures can be explained by the fact that these do not represent average temperatures. The heat given off by the freezing fruits undoubtedly caused considerable variation in air temperatures throughout the baskets. The fact that the fruits that undercooled the most began to freeze at 25°, or 1 to 2 degrees below this point, indicates that probably the minimum air temperatures reached within the baskets approximated 23°, but this is only a conjecture.

At the close of the test all the fruits in the baskets were inspected. In the jolted basket 4 fruits were unfrozen, 10 were partially frozen, and 22 were frozen solid. In the undisturbed basket 20 were not frozen, 6 were partially frozen, and 10 were frozen solid.

SUMMARY

The skin of greenhouse-grown tomatoes is frequently more or less transparent, exposing some of the vascular tissue beneath. This condition is sometimes erroneously considered an indication of chilling or freezing injury.

Experimental tests were conducted with three lots of normal, firm, ripe greenhouse-grown tomatoes, received December 8, 1930. Two lots were placed at 17° and 30° F., respectively, for 24 hours, after which they were transferred for 24 hours to 50°, at which temperature a check lot had remained since the beginning of the test. The lot at 17° constituted an entire basket packed and wrapped as received, but with thermocouples inserted into fruits in different locations. At the close of the test the check lot and the lot originally at 30° for 24 hours showed no injury, whereas the lot at 17° showed nearly all the specimens injured except a few from the center of the top layer.

The characteristics of the freezing injury are described.

At 17° F. freezing started in the specimen in the bottom corner after 13½ hours, the specimen having undercooled below the freezing point, after 6½ hours, to 25.5° F. The fruit in the top center of the basket began to freeze after 20 hours' exposure.

The freezing points of the fruits varied from 30° to 30.5° F.

Another lot of tomatoes was received April 30, 1931. Thermocouples were inserted into specimens in different locations and the baskets again wrapped as received and placed in cold storage at 20° F. While one basket remained undisturbed, the other was put in a jolting apparatus to simulate conditions met with during transit. The fruit in the undisturbed basket undercooled lower than that in the jolted basket, in which the undercooling period was short, although one fruit in the top layer remained undercooled for about 10 hours, and one did not freeze at all during the test. The first fruits in the jolted basket, located in the bottom corner, started to freeze after about 6 and 10½ hours without perceptible undercooling. Fruits in corresponding positions in the undisturbed basket started to undercool after about 8 hours; one remained undercooled without freezing, the other started to freeze after about 16 hours.

The lowest undercooling point (27.7° F.) reached in the jolted basket was in a fruit located in the center of the top layer, while a temperature of 23.2° was reached in a fruit at the side in the top layer of the undisturbed basket.

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